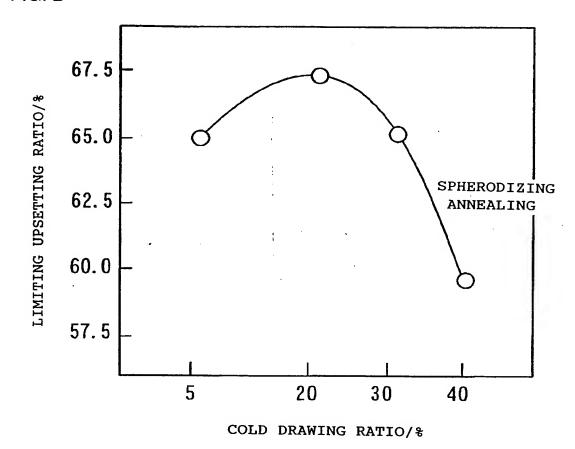


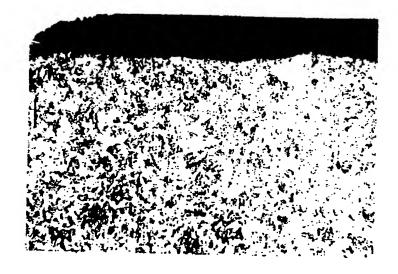
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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FIG. 2



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Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
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FIG. 3

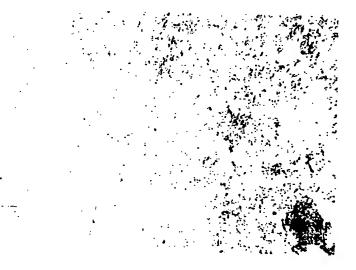




Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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FIG. 4

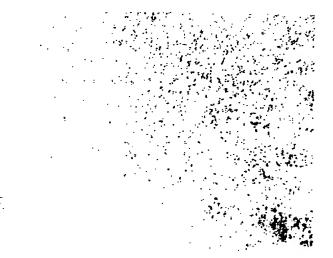




Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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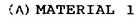
FIG. 5



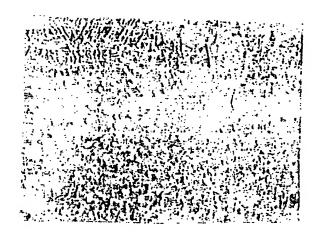


Inventor: Ando, et al
Docket No.: 12052.33USD1
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FIG. 6

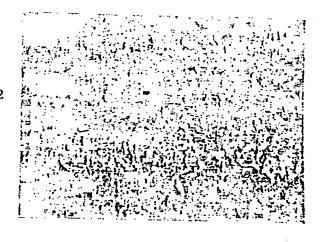


ASPECT RATIO = 506 %



(B) MATERIAL 2

ASPECT RATIO = 347 %



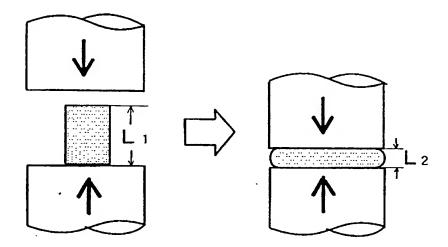
(C) MATERIAL 3

ASPECT RATIO = 300 %



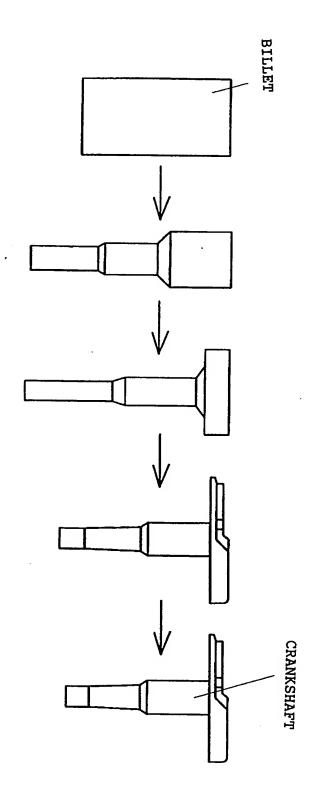
Inventor: Ando, et al
Docket No.: 12052.33USD1
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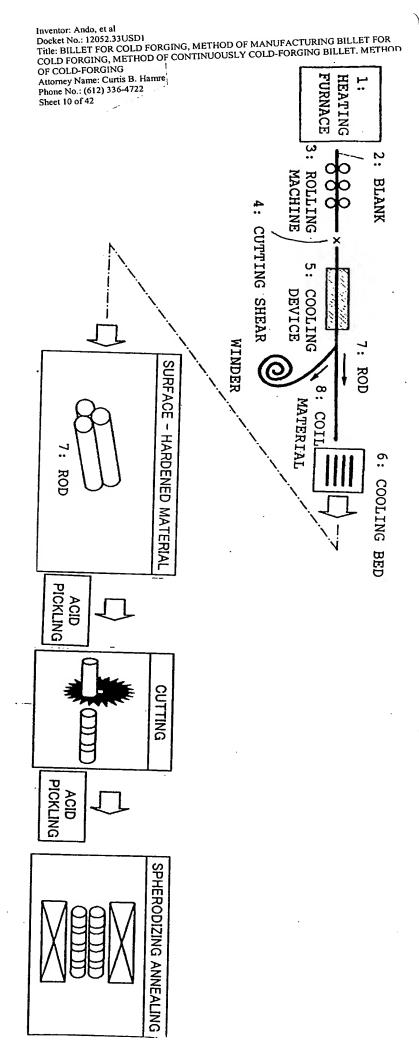
FIG. 8



Inventor: Ando, et al
Docket No.: 12052.33USD1
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FIG. 9

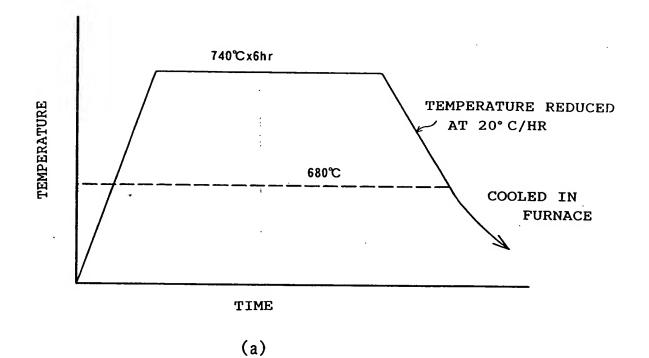


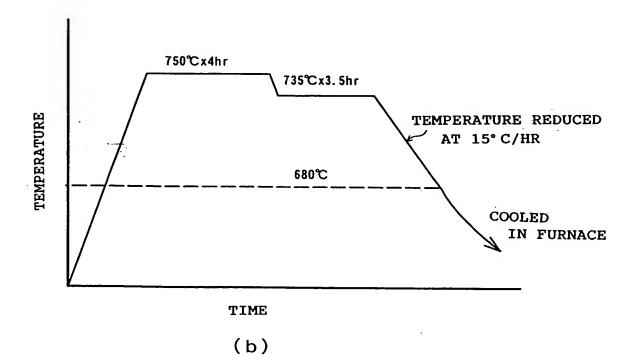


Inventor: Ando, et al
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Attorney Name: Curtis B. Hamre

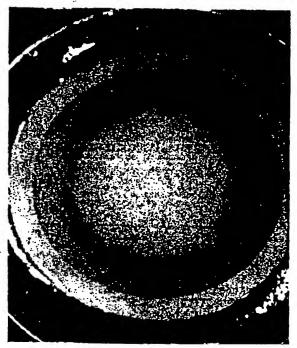
Attorney Name: Curtis B. Hamre Phone No.: (612) 336-4722 Sheet 11 of 42

FIG. 11

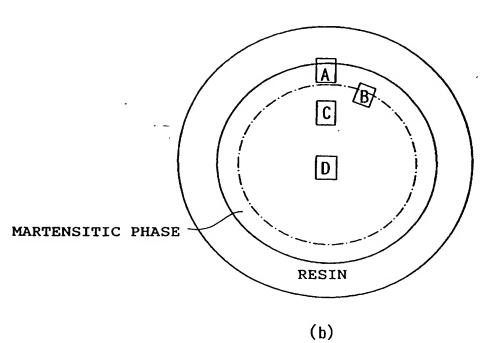




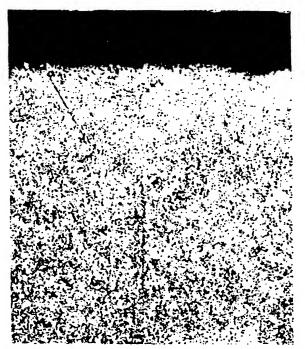
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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MARTENSITIC MATERIAL
(a) PRIOR TO SPHERODIZING ANNEALING × 2. 1

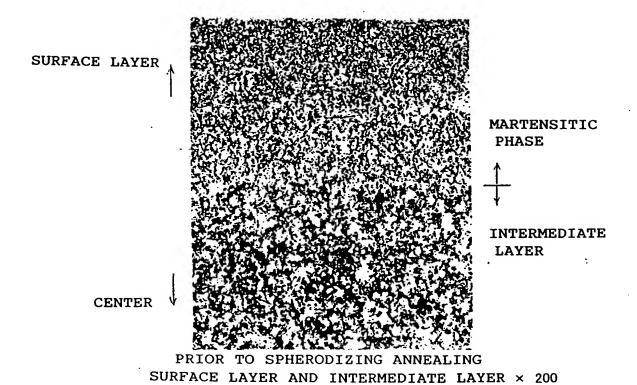


Inventor: Ando, et al
Docket No.: 12052.33USD1
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PRIOR TO SPHERODIZING ANNEALING SURFACE LAYER  $\times$  100

FIG. 14



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### FIG. 15

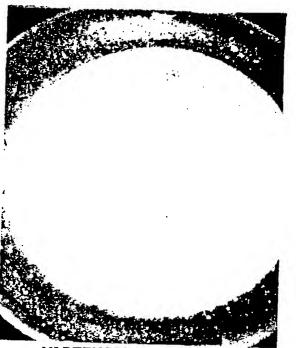


PRIOR TO SPHERODIZING ANNEALING 1/2 R PART  $\times$  400

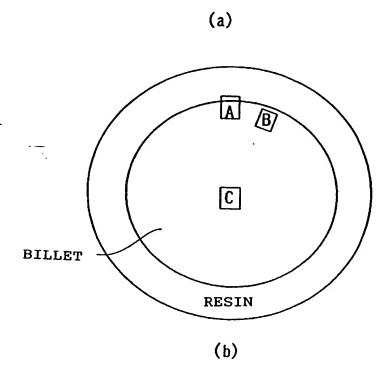


PRIOR TO SPHERODIZING ANNEALING CENTRAL PART × 400

Inventor: Ando, et al
Docket No.: 12052.33USD1
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MARTENSITIC MATERIAL
AFTER SPHERODIZING ANNEALING PATTERN 1
× 2. 1



Inventor: Ando, et al

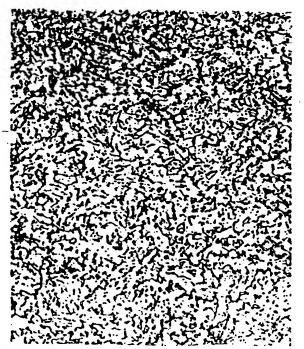
Docket No.: 12052.33USDI
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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FIG. 18



AFTER SPHERODIZING ANNEALING PATTERN 1 SURFACE LAYER × 100

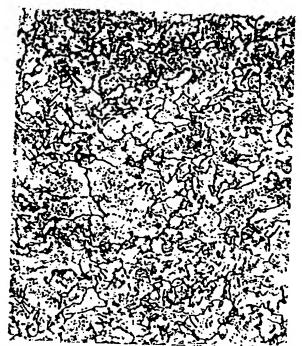
FIG. 19



AFTER SPHERODIZING ANNEALING PATTERN 1 SURFACE LAYER × 400

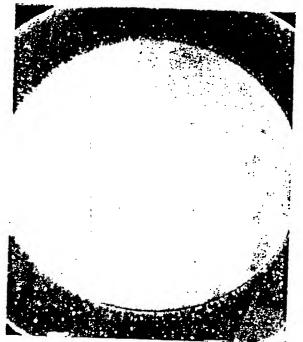
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Inventor: Ando, et al
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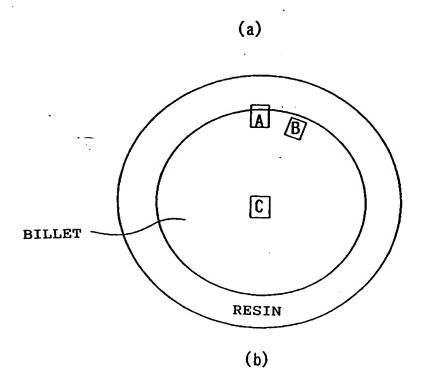


AFTER SPHERODIZING ANNEALING PATTERN 1 1/2 R PART × 400

Inventor: Ando, et al
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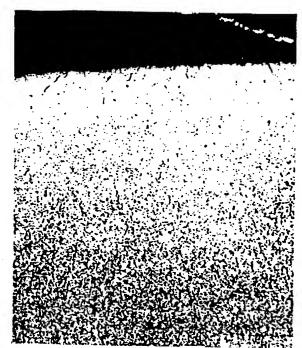


MARTENSITIC MATERIAL
AFTER SPHERODIZING ANNEALING PATTERN 2
× 2. 1

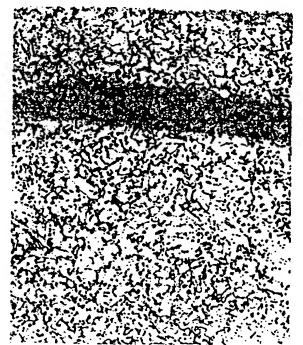


Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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#### FIG. 22



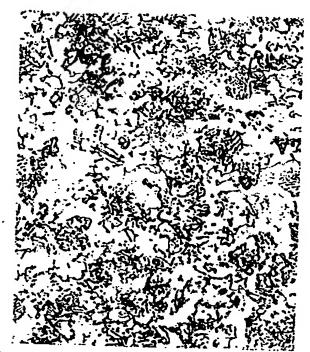
AFTER SPHERODIZING ANNEALING PATTERN 2 SURFACE LAYER  $\times$  100



AFTER SPHERODIZING ANNEALING PATTERN 2 SURFACE LAYER × 400

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AFTER SPHERODIZING ANNEALING PATTERN 2 1/2 R PART  $\times$  400

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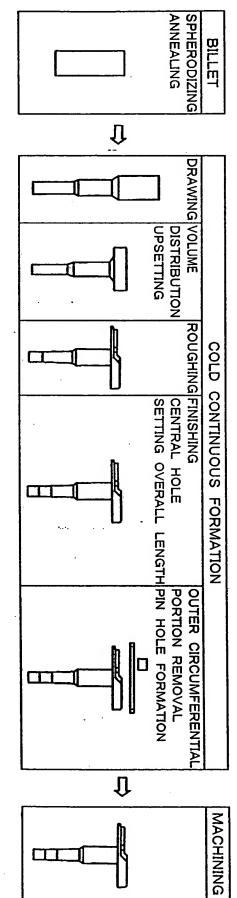
FIG. 25

SOFTENING BILLET Û DRAWING VOLUME COLD FORMATION UPSETTING DISTRIBUTION ROUGHING FINISHING SETTING OVERALL LENGTH PIN HOLE FORMATION CENTRAL HOLE Û STEP SOFTENING INTERMEDIATE HEAT TREATMENT COLD FORMATION PORTION REMOVAL OUTER CIRCUMFERENTIAL Û FINISHING

FIG. 26

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FIG. 27

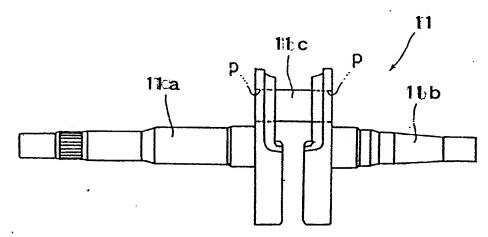
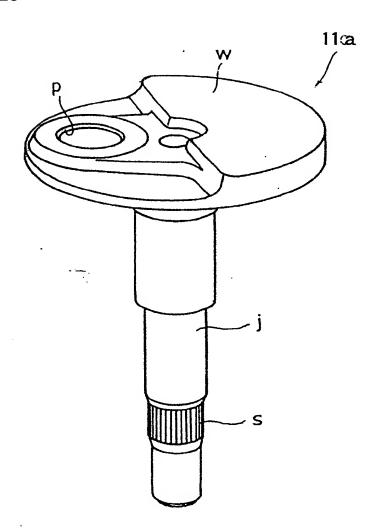
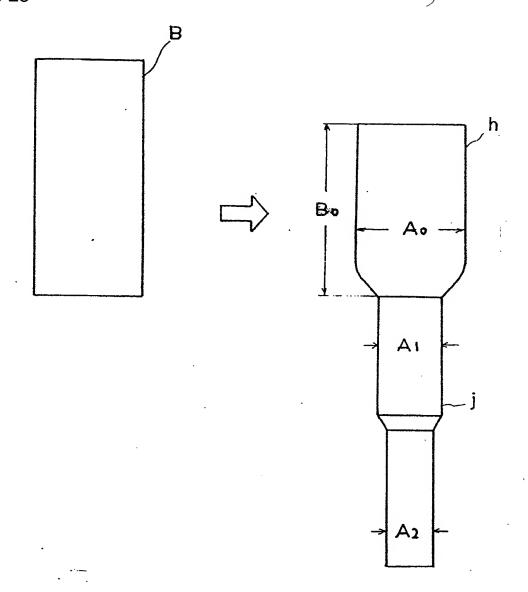


FIG. 28



Inventor: Ando, et al
Docket No.: 12052.33USD1
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FIG. 29

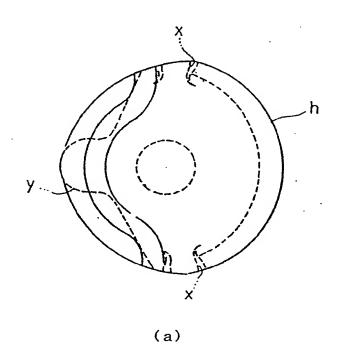


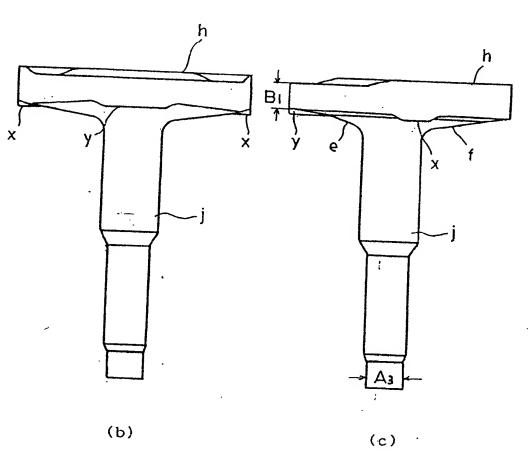
(a)

(b)

Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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Attorney Name: Curtis B. Hamre
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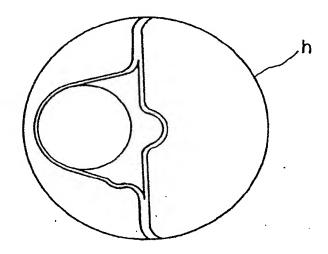
FIG. 30

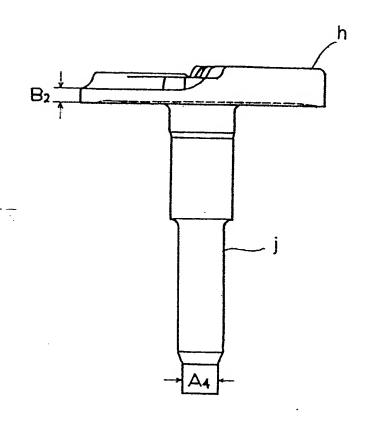




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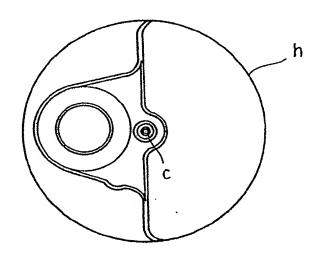
FIG. 31

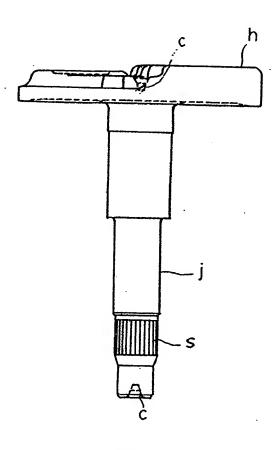




Inventor: Ando, et al
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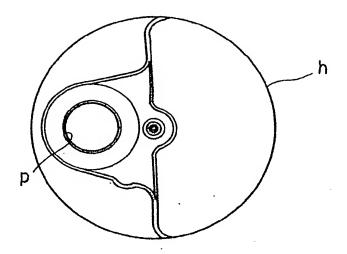
FIG. 32

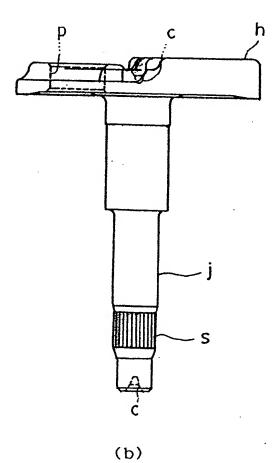




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FIG. 33



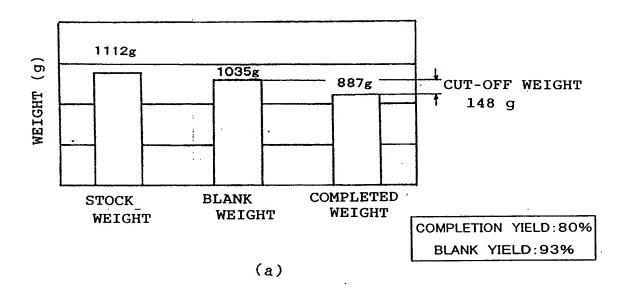


Inventor: Ando, et al
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Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
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Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722

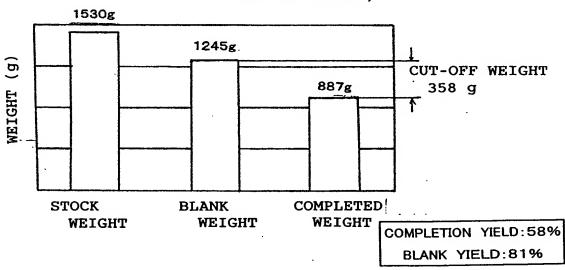
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FIG. 34

#### (INVENTIVE COLD-FORGING METHOD)

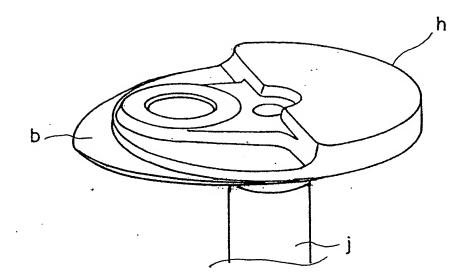


#### (CONVENTIONAL COLD-FORGING METHOD)



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FIG. 35

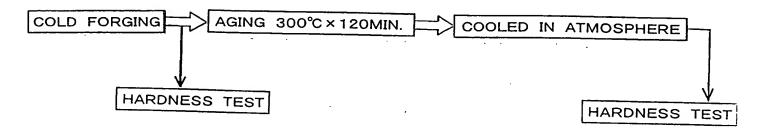


Inventor: Ando, et al

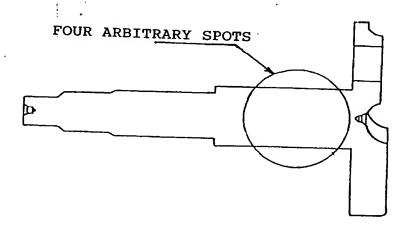
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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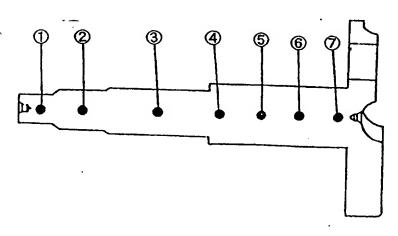
FIG. 36



(a)



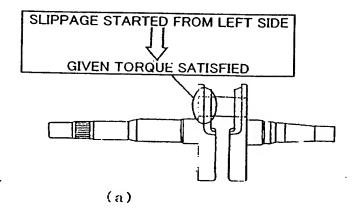
(b)



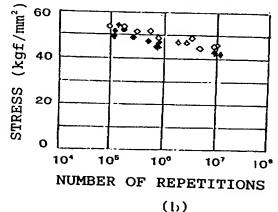
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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FIG. 37

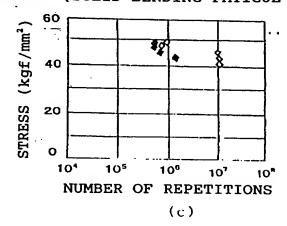
#### SLIP TORQUE



# S - N CURVE (ROTATIONAL BENDING FATIGUE TEST)



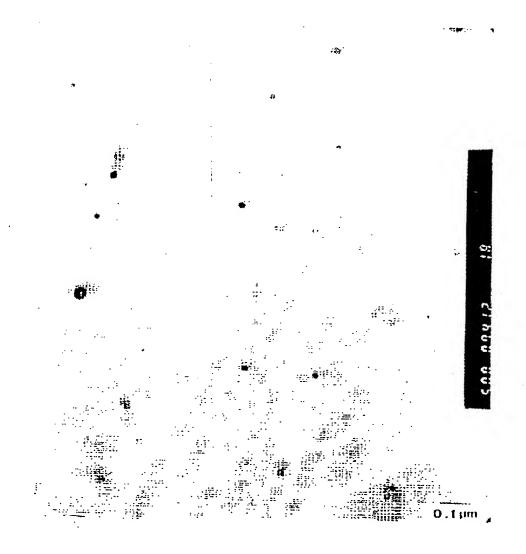
# S - N CURVE (SOLID BENDING FATIGUE TEST)



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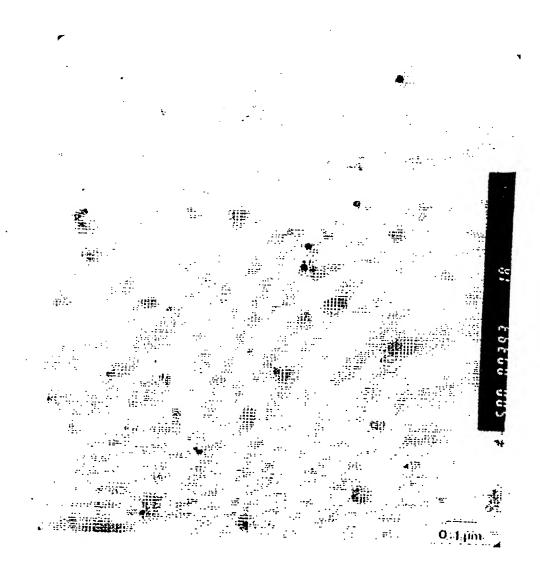
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
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FIG. 38



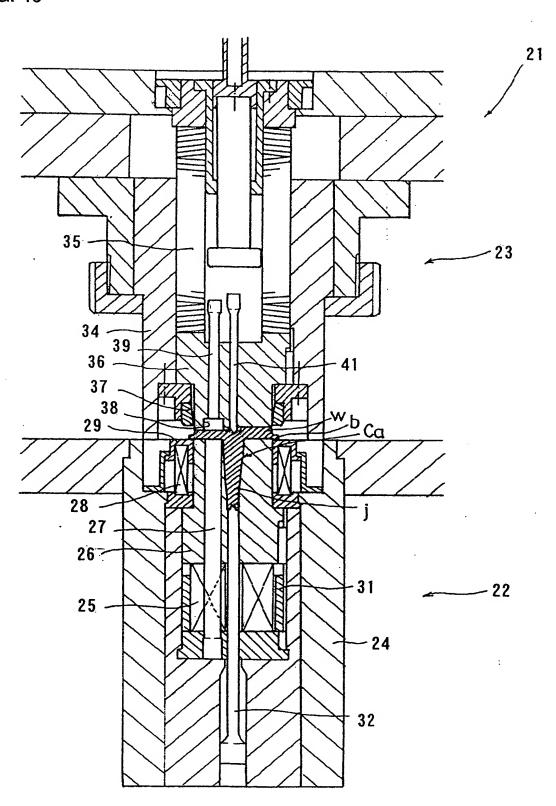
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
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FIG. 39



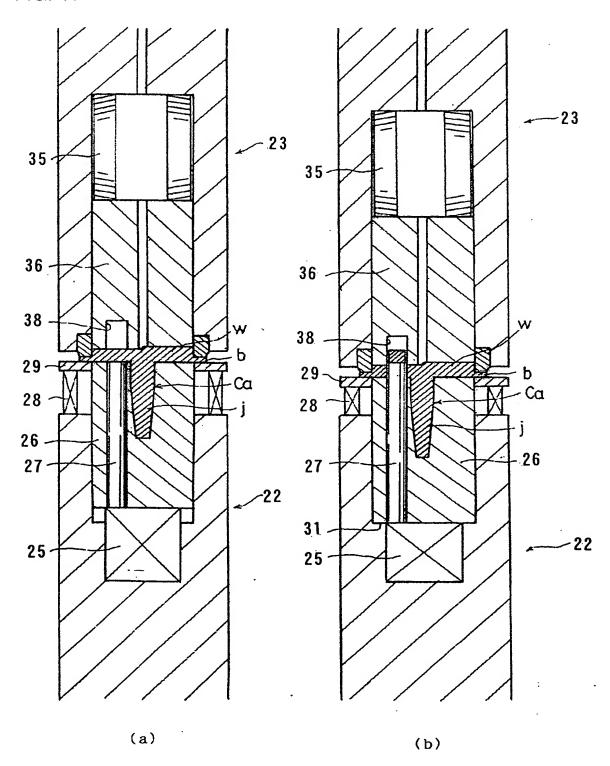
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
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FIG. 40



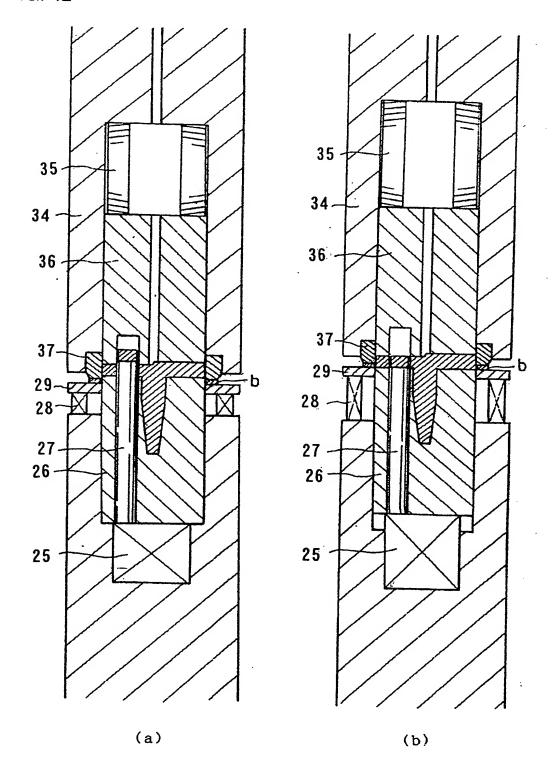
Inventor: Ando, et al
Docket No.: 12052.33USD1
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FIG. 41



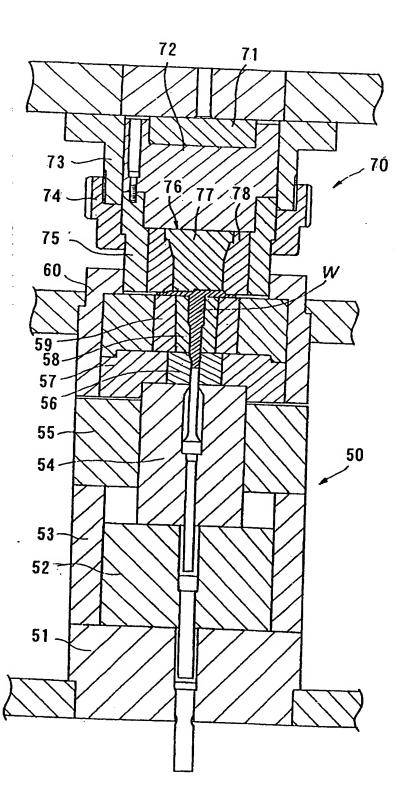
Inventor: Ando, et al
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COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
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FIG. 42



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FIG. 43



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FIG. 44

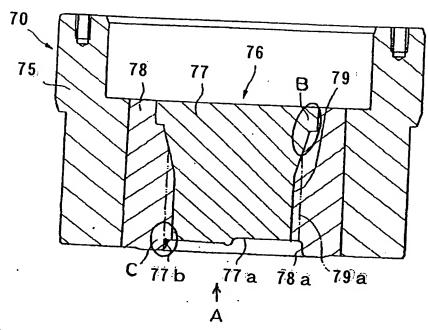
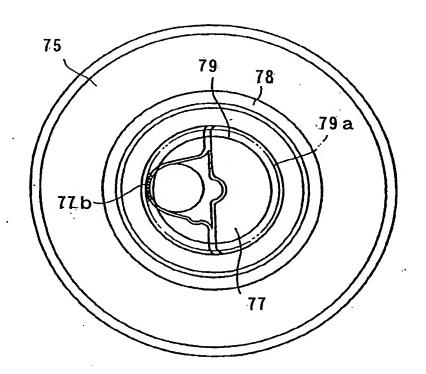


FIG. 45



Inventor: Ando, et al
Docket No.: 12052.33USD1
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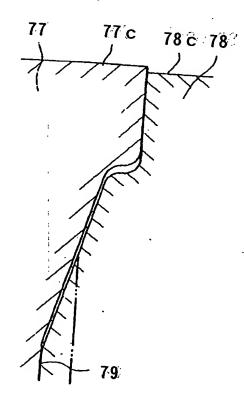
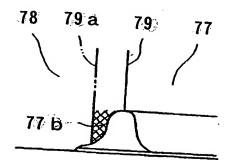
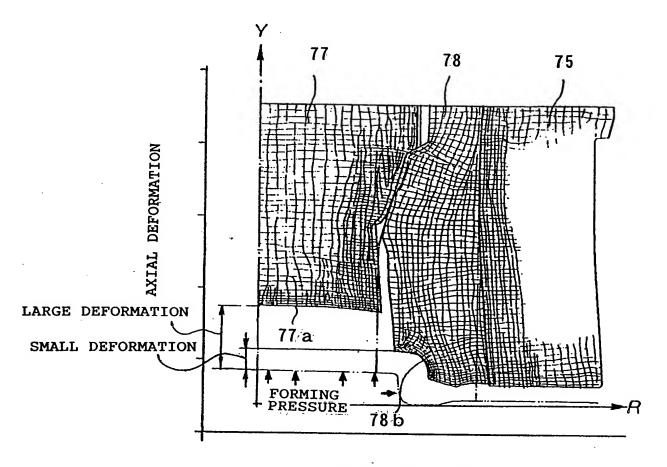


FIG. 47



Inventor: Ando, et al
Docket No.: 12052.33USD1
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FIG. 48



RADIAL POSITION

Inventor: Ando, et al
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OF COLD-FORGING
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FIG. 49

	Billet manufacturing process					Aspect ratio	Crack
	Spherodizing annealing prio to drawing			Spherodizing	Shot bonderizing	of carbide	percentage % N=100
Material 1	None	None	0	0	0	506	35%
Material 2	None	(20%) O	0	0	0	347	5%
Material 3	0	(20%) O	0	0	0	300	0%

Aspect ratio (%) =  $b/a \times 100$ 

